MODULAR TRANSVERSE FLUX MOTOR WITH INTEGRATED BRAKE

Technical Field

This invention relates to transverse flux motors in which the output torque can be adjusted by stacking rotor/stator modules to fit the needs of applications, such as elevators, and optionally having an integrated brake.

Background Art

As an example of art needful of the present invention, elevator machines represent a major portion of the material costs of an elevator. Elevator machines require slow rotating speeds and must provide decades of maintenance-free service. For low noise, smooth operation, low cost, and a compact drive system, gearing is to be avoided if possible. One important factor in motor selection is the amount of torque output per unit of active material, either mass or volume, including the core steel, the conductor wire, and the permanent magnets. Maximum torque requirements for an elevator machine are determined by the maximum imbalance, which is generally about one-half of rated load plus maximum cable mass mismatch, together with the sheave diameter and roping arrangement (1:1, 2:1, etc.).

Conventional, rotating field electric machines have phase windings integrated into one core structure. For larger torque capability, a longer core of stacked laminations is required, with different phase windings, which in turn require different winding fixtures and other manufacturing equipment. The stator of conventional motors have end turns which extend beyond the useful flux-producing portion of the motor. These coil extensions render it difficult to achieve compact motor/sheave combinations, and to integrate brakes or other auxiliary structures with the motors.

To reduce the number of motor models required for a product line, some of the elevator models that share a motor type with other elevator models are oversized for their torque requirements. Having a large number of motors without common parts raises the cost of materials, set-up, manufacture, and warehousing spare parts.

Disclosure of Invention

Objects of the invention include: improved motors for elevators; motors that provide high torque at low speed; motors in which torque can be increased simply by adding modular phases; motors in which the torque can be increased without requiring a total change of the windings; motors with high efficiency and good power factor; motors which have a high volumetric torque density; motors with relatively shorter assemblies with no coil end turns, and thus lower loses; motors having simple stator windings; motors which use significantly less copper and require less manufacturing labor than similarly rated permanent magnet brushless

motors; and motors which can be built with identical modules to permit small steps in torque ratings using identical parts.

According to the present invention, an electric motor, suitable for driving elevator sheaves, consists of rotor/stator modules, one module per phase of the driving current, the motors being built up of identical rotor/stator modules, one or more modules per phase, in order to select the proper torque rating of the motor.

According further to the present invention, a brake may be disposed integrally, on the same shaft and contiguous to a rotor/stator module of a transverse flux motor.

A motor according to the present invention provides higher torque per unit volume than a conventional motor, has practically constant efficiency for constant stator torque and speed, has improved power factor (due to the absence of end-turn leakage flux), and is capable of a power factor which increases with the number of poles. A motor according to the invention has practically constant efficiency in ranges from about 50% to about 120% of the rated shaft torque at rated operating speed. The invention has shorter ferromagnetic core and shaft and utilizes 30% less copper in conductors and ferromagnetic core volume than comparable permanent magnet brushless motors, and has no coil end turns, thus producing a shorter, lighter motor. The invention provides motors having only a single, annular coil per phase regardless of the number of poles.

Other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of exemplary embodiments thereof, as illustrated in the accompanying drawing.

Brief Description of the Drawings

Fig. 1 is a external perspective view of a motor according to the invention as it may attach to the sheave of an elevator.

Fig. 2 is an exploded perspective view of a three-phase motor and integral brake according to the present invention.

Fig. 3 is a perspective view of an assembled rotor/stator module.

Fig. 4 is an exploded perspective view of the module of Fig. 3.

Fig. 5 is a sectioned elevation taken on the line 5-5 of Fig. 3.

Fig. 6 is a partial perspective view of the interface between the rotor and the stator of a rotor/stator module.

Fig. 7 is a partial, expanded elevation of the section of Fig. 5.

Fig. 8 is a sectioned elevation of the motor and integrated brake illustrated in Figs. 1-7.

Fig. 9 is a partial expanded view of the integrated brake shown in Fig. 8 with the brake released.

Fig. 10 is an expanded view of the integrated brake of Fig. 8 with the brake engaged.

Figs. 11 and 12 are simplified side sectional views illustrating modularity of the present invention.

Fig. 13 is a macro function diagram of a method of modular motor manufacture.

Mode(s) for Carrying Out the Invention

Referring to Fig. 1, a motor 12 with integral brake of the present invention includes a left end plate 13 and a right end plate 14 which are secured to an enclosure 15 by suitable fasteners, such as radial screws 16 in low torque applications. In large motors, the endplates may be secured with axial bolts threaded into a thicker enclosure. The motor rotates a driven member which, for instance, may be an elevator sheave 17. The motor enclosure has a mounting base 19. The enclosure 15 is omitted in Fig. 2 for clarity.

Referring to Fig. 2, the end plates 13, 14 have bearings therein, only the bearing 41 for the right end plate being shown in Fig. 2. Although not shown herein, the bearings may have covers to aid in lubrication and prevent ingress of dirt, as is known. A shaft 21 has a slot 23 to receive a key 24 which engages a plurality of rotor/stator modules 28-30, each of which has a corresponding slot 22 in its rotor so as to transfer torque from the rotor to the shaft. A spacer 33 (also see Fig. 8) prevents the rotor of module 28 from engaging the outer race of the bearing 20. A spring clip 34 in a notch 35 in the shaft 21 engages the rotor of module 30, preventing relative axial movement between the modules 28-30 and the shaft 21, thereby holding the modules 28-30 contiguous with each other and in contact with the spacer 33. Similarly, to prevent rightward movement of the shaft 21, a spring clip 36 in a notch 37 (see also Fig. 8) contacts the inner race 40 of a bearing 41 on the right end of the shaft, shown only in Figs. 8-10.

A brake disc 43 is engaged to a hole 44 in the shaft 21 by a pin 46 on which the disc 43 may slide through an elongated slot 47. A brake assembly 49 includes an annular frame 50 having an annular groove 51 for brake releasing coils, and a land 52 against which stacked wave springs 53 will press so as to engage the brake when the brake releasing coil is disenergized. A return spring 56 will cause the brake disc to assume a neutral position where it will neither contact the right end plate 14 nor the frame 50 when the brake releasing coil is energized. This is described in detail hereinafter with respect to Figs. 9 and 10.

Referring to Figs. 3-7, each rotor/stator module includes a pair of soft magnetic stator plates 60, 61 separated by a soft magnetic annulus 63 that contains an annular coil 64. The stators 60, 61 have oppositely-poled poles, shown in Fig. 6 to be north poles on stator plate 61 (there concurrently are south poles on stator plate 60), but the polarity alternates with the current in the coil 64. The poles 67 are separated by air gaps 68.

The rotor of each rotor/stator module 28-30 consists of an annular soft magnetic base portion 71 with a hole 72 for the shaft 21. On the surface of the base portion 71, two rows of hard permanent magnets 74-77, which may be NdFeB, are separated by a non-magnetic spacer

78 (but there could be air between the two rows of magnets 74-77). The south pole 74 in one row of magnets is in axial alignment with a north pole 76 in the other row of magnets, and the north pole 75 in the one row of magnets is in axial alignment with a south pole 77 in the other row of magnets. Thus, for each pole 67 there are a pair of magnets 74, 75. Alternative configurations may have variations in magnet placement, size, shape and consistency. The requirement is to have an alternating field, multiple magnets, or multi-poled segments. The magnets 75-77 are shown in Figs. 4 and 6 as being spaced from adjacent magnets; however, they may be touching. In fact, they may comprise a solid ring of magnetic material or an extension of the magnetic material of the base 71 which is polarized to provide the appropriate polarization. The base portion 71 has polarities created therein, as illustrated in Fig. 6, which are opposite to the air gap polarity of each of the magnets 74-77 and provides an effective return path for the magnetic fields.

Referring to Fig. 7, the flux path illustrated by an arrow 79 reverses with current. Pins 81 (Fig. 4) press fit into the annulus 63 engage holes 82 in the stator plates 60, 61 to maintain module alignment.

Referring to Figs. 9 and 10, the frame 50 of the disc brake 49 includes a pair of alignment holes 83 (Fig. 10) within which alignment pins 84 are free to slide, the pins 84 being press fit within holes in the stator 60 of the rotor/stator module 30. This keys the frame to a stationary part of the motor to prevent the disc brake assembly 50 from rotating against the force of the brake disc 43 when the brake is applied. Alternatively, the frame may be keyed to any suitable stationary part of the motor, such as the enclosure 15. A pair of brake coils 86, 87 are disposed in and adjacent to the groove 51. Each coil has sufficient strength so as to release the brake, the two coils both being provided for redundant safety. A shoulder 90 (Fig. 9) engages the pin 46 when the brake is released so that the return spring 56 will move the brake disc 43 away from the end plate 14 while the pin 46 acting on the shoulder 90 (Fig. 9) will prevent the spring 56 from causing the brake disc 43 to drag on the disc brake assembly 50.

The wave springs 53 may be of such size and number as is determined necessary to provide the desired brake torque. They may for instance comprise crest-to-crest springs as shown in the web site www.smalley.com/spring and provided by the Smalley Steel Ring Company of Lake Zurich, IL, USA.

As seen in Fig. 10, a brake friction pad 92 on the brake disc will engage the end plate 14 of the motor when the brake is operated by the springs 53 with the coils 86, 87 not energized. Similarly, a brake friction pad 93 will engage the frame 50, which in turn is anchored to the stator 60 by the pins 84, when the brake is engaged as shown in Fig. 10. Thus, the brake is integral with the motor assembly, reducing the space, mass and parts count, and thereby providing a more efficient and economical unit.

Instead of using the rotor/stator arrangement described with respect to Figs. 1-7 herein, the present invention may be implemented utilizing transverse flux permanent magnet

machines employing a variety of topographies, such as those disclosed in Harris, M.R., "Comparison of Flux-Concentrated and Surface Magnet Configurations of the VRPM (Transverse-Flux) Machine" ICEM '98 Vol. 2, 1998 Istanbul, Turkey, pp. 1110-1122, and in references cited therein. The only critical requirement is that the torque direction be perpendicular to the magnetic flux lines.

The manner in which the modular design of the present invention may be utilized in order to properly size motors for a variety of configurations utilizing the same rotor/stator modules is illustrated in Figs. 8, 11 and 12. Each module comprises one phase. The motor of Figs. 1-10 has three modules 28-30, and would be operated by four phase AC power provided, for instance, by a variable voltage, variable frequency power converter (VVVF drive) of a well-known variety. Assuming that each module contributed sufficient torque to provide a 5 ton motor, the motor of Figs. 1-10 would comprise a 20 ton machine.

Illustrated in Fig. 11 is a three-phase, 15 ton machine 100, as described in Figs. 1-10. The VVVF drive 102 provides phase related separate drive currents over related lines 104, 105, 106 to corresponding modules 28-30. Alternatively, for complete modularity, each module may have its own, separate drive.

In Fig. 12, an elevator machine 110 may comprise six modules 28-30, 28a-30a, working on the common shaft 21; the modules could be separately driven by six different phases of AC power, or the modules 28-30 and the modules 28a-30a could be driven in parallel with the same three phases of AC power. However, six-phase power would provide smoother operation and lower losses, as is known.

Similarly, modules capable of producing more or less torque per module could be arranged with as little as a pair of modules being driven by two-phase power, or six or more phases driven by three- or six- or more-phase power. A three-phase drive, for instance, can drive a motor consisting of 3N stator modules where N may be 1-4 or some other positive small integer, where similar modules share the power from the three-phase drive.